Biol Invasions (2019) 21:961–982
https://doi.org/10.1007/s10530-018-1875-0

ORIGINAL PAPER

Assessing local attitudes and perceptions of non-native species to inform management of novel ecosystems

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Received: 12 February 2018 / Accepted: 7 November 2018 / Published online: 12 November 2018

Abstract The formation of novel ecosystems by non-native species poses management challenges that are both socially and ecologically complex. Negative attitudes towards non-native species can complicate management in cases where non-native species provide ecosystem service benefits. Due to their intentional introduction over a century ago, non-native mangroves in Hawai'i present a unique case study. Although some have called for eradication of mangroves from Hawai'i, an active management approach may ultimately offer the greatest benefits to both the ecosystem and society by allowing mangroves to persist in locations where they provide habitat and crabbing access, while limiting their extent in other locations to protect native bird habitat and allow for beach and ocean access. We evaluated (1) attitudes and perceptions about non-native mangroves, (2) factors influencing these attitudes, and (3) support for different management approaches by surveying residents of Moloka'i, Hawai'i (n = 204). Negative attitudes towards mangroves were influenced by a lack of reliance on mangroves for benefit and a concern about threats to Moloka'i's coast. Active management was supported by 88% of residents, while 41% supported eradication. Among the 88% in favor of active management, 24% of written in responses expressed a need for maintaining the benefits of mangroves and 67% described reducing the negative impacts, while 4% acknowledged both the benefit and harm the species has on the environment. As successful non-native species management may be dependent on local support, we emphasize that understanding human attitudes and perceptions is beneficial for non-native species managers in any location. Results from our study highlight the importance of understanding social attitudes towards non-native species management strategies from propagation to eradication. We conclude with a framework for integrating stakeholder attitudes and beliefs into novel ecosystem management.

Keywords Values · Novel ecosystems · Red mangrove · Ecosystem services · Socio-ecological systems

Introduction

Novel ecosystems, comprised of species combinations and abundances not previously present within a given

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10530-018-1875-0) contains supplementary material, which is available to authorized users.

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ecosystem, are becoming increasingly abundant (Hobbs et al. 2006, 2014). These ecosystems can be created by non-native species, changing land use and climatic conditions, and human behaviors, posing challenges for natural resource managers (Truitt et al. 2015). The difficulty of balancing limited scientific information about the costs and benefits of non-native species and novel habitat coupled with the often strong attitudes and perceptions held by local stakeholders about such ecosystems complicate management decision-making. Given these complexities, integration of local stakeholder aspirations and perceptions into biodiversity conservation has become more commonplace (Mehta and Kellert 1998). Such efforts facilitate community participation, support, and benefits of sustainable natural resource management and can enhance project success (Gillingham and Lee 1999). The first step to such integration is to identify people's values and beliefs, attributes that provide the foundation for attitudes about natural resources and perceptions of management actions and institutions (Ajzen 2001; Stern 2008).

Both scientific and societal attitudes and perceptions of non-native species have demonstrated a bias against such species as reflected in assumptions made on intrinsic and instrumental values of the species, the language used to describe them, and the types of studies conducted (Slobodkin 2001; Gurevitch and Padilla 2004; Stromberg et al. 2009), all of which can impede consideration of potential benefits (Schlaepfer et al. 2011). As rapid globalization with increasing international trade and intercontinental transportation continue, the rate of non-native introductions is expected to increase (Meyerson and Mooney 2007; Katsanevakis et al. 2014; Tittensor et al. 2014). Although invasive species can negatively affect their new environments, they may provide ecosystem services in areas experiencing rapid climate-related or land use changes (Schlaepfer et al. 2011; Tassin and Kull 2015). However, this potentially beneficial role in supporting new or replacing previously lost ecosystem services is studied less often than their negative impacts (Charles and Dukes 2007; Estévez et al. 2015, but see Pyšek et al. 2008; Ewel and Putz 2004; Tassin and Kull 2015). Assessments must recognize that many natural conditions have been altered and non-native species can be a key part of ecosystem function with potentially beneficial effects on other species (Lugo 2004; Goodenough 2010; Schlaepfer et al. 2011; Eviner et al. 2012; Rodewald 2012; Lugo et al. 2012; Tassin and Kull 2015).

Managing non-native species is as much a social issue as it is a scientific one (Reaser 2001). From functioning as agents of introduction (intentional or accidental) to dealing with ecological changes from, and making management decisions about non-native species, humans are involved in the entire invasion process and, therefore, the issue is both a socio-economic and ecological problem (García-Llorente et al. 2008; Campbell and Hewitt 2018). Truitt et al. (2015) argue that management needs to consider ecological conditions, ecosystem services, management resources, and stakeholder interests and priorities to determine the most appropriate action.

Where non-native species management programs are well established, community surveys to better understand people's perceptions towards non-native species and their reactions to proposed management are becoming more common (Johnston and Marks 1997; Fraser 2001, 2006; Bardsley and Edwards-Jones 2007; Sharp et al. 2011; Wald et al. 2018). Though recent projects have shown increasing efforts to incorporate social viewpoints, overall, less attention has been paid to public attitudes towards invasive or non-native species and their management compared to their ecological impacts, likely due to the difficulty in measurement (García-Llorente et al. 2008; Estévez et al. 2015; Campbell and Hewitt 2018, but see Simberloff 2005; Fraser 2006; Hulme 2006; Bremner and Park 2007; Fischer and Van Der Wal 2007). Addressing factors influencing public attitudes has led to greater support and increased success for biodiversity management measures, policies, and planning decisions (Balram and Dragićević 2005; Bremner and Park 2007; Fischer and Van Der Wal 2007). Thus, for more successful management outcomes, there is an urgent need to better understand societal perceptions toward non-native species (García-Llorente et al. 2008).

Figure 1 provides a framework to assess and incorporate diverse perceptions and attitudes into decision-making around novel ecosystems created by non-native species. Specifically, this framework directs managers and scientists to identify relevant stakeholders by assessing the scope and priorities of any given management project. As novel environments are complex socio-ecological systems, consideration of both stakeholder attitudes and scientific

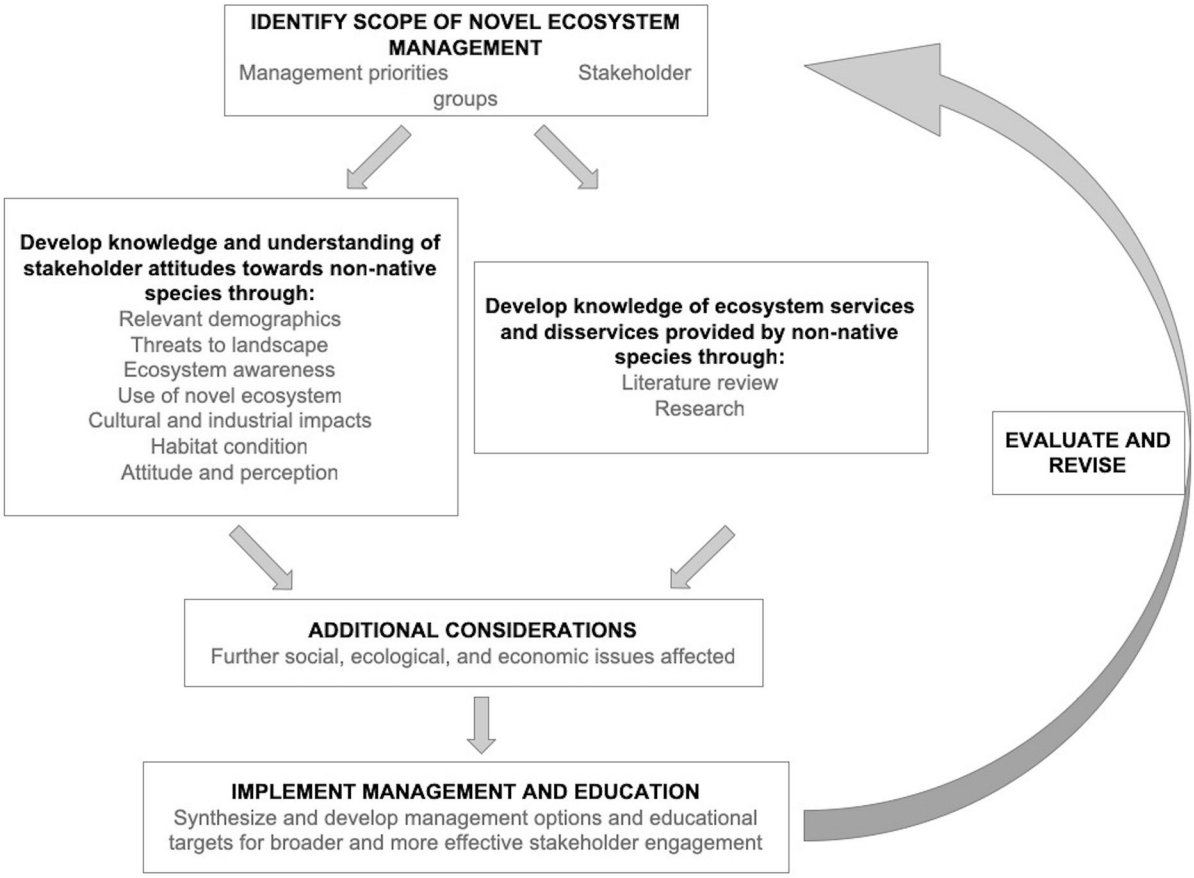

Fig. 1 A framework for non-native species to optimize novel ecosystem management through consideration of stakeholder socio-cultural attitudes and values

research on services and disservices of the novel ecosystem are important (see Evers et al. 2018). Information can then be synthesized to develop management options and educational goals that provide more effective stakeholder engagement. For this study, attitude is considered a learned and summative assessment that influences thoughts and actions (Ajzen and Fishbein 1980; Vogel and Wanke 2016). As attitudes are not directly observable, methods to assess them often involve questionnaires (Dawes 1972). Previous studies have identified demographics, place connections and value systems, perceptions of costs and benefits, knowledge, and distrust in conservation authorities as factors that influence attitudes towards the environment and public opposition to management (Schultz and Zelezny 1999; Blake 2001; Lakhan and Lavalle 2002; Genovesi 2007). Incorporating these variables into the framework provides an integrated and adaptive approach to managing novelty in complex socio-ecological systems in an ever-evolving world.

This study explores residents' perspectives on non-native mangroves and their management on the Hawaiian Island of Moloka'i. To provide an understanding of residents' evaluation of non-native mangroves, including attitudinal influences that can be used to predict the degree of public support and/or opposition managers may experience, we administered a questionnaire to Moloka'i residents and analyzed their responses. Specifically, the study addresses the following questions:

1. What are residents' attitudes towards non-native mangroves?
2. What factors influence these attitudes?

3. How may attitudes towards mangroves and coastal management influence support of mangrove management practices?

Methods

Study area

Mangroves on Moloka'i, Hawai'i present a unique case study to examine societal perceptions towards non-native species management due to the intentional nature of their introduction and the length of time since introduction. On Moloka'i, human land use changes since the late 1800s led to the introduction of red mangroves (*Rhizophora mangle*) in an attempt to reduce sedimentation on near-shore coral reefs (Roberts 2000). Since their introduction in 1902 (Wester 1981; Allen 1998; Field et al. 2007), mangroves have become well established. Although numerous conservation and restoration efforts exist for native mangroves throughout the tropics, in the Hawaiian Islands there are removal and eradication programs (Allen 1998; Chimner et al. 2006; Siple and Donahue 2013). Despite these localized removal programs, eradication of invasive species is expensive, time-consuming, and is not guaranteed to be successful (Pimentel et al. 2005). Specifically in Hawai'i, mangrove removal has been estimated to cost $108,000/ha on sites where machinery can operate and at least $377,000/ha on sites where mangroves are removed by chainsaw on floating walkways (Allen 1998). In their native habitat, mangroves provide a multitude of ecosystem services including buffering impacts from terrestrial land uses on nearshore coastal reefs. The health of Moloka'i's near-shore coral reefs is of concern due to sedimentation caused by previous and current land use conditions (Roberts and Field 2008), and the novel Hawaiian mangrove ecosystem may play a role in buffering this reef stressor (D'Iorio 2008). In addition, as climate change impacts the frequency and intensity of hurricanes and tropical storms (Michener et al. 1997), non-native mangroves on Moloka'i may aid in coastal climate adaptation when considering mangroves' role as a natural buffer for storm events (Spalding et al. 2010). Finally, public support of mangrove management in Hawai'i remains undetermined; gaining an understanding of which management practices may be supported and why would aid in management planning. Given the pressure to manage Moloka'i's mangroves, it is important to better understand Moloka'i residents' (population 6885; US Census 2014) uses of and attitudes towards non-native mangroves and their management.

Data collection

To assess both attitudes and support for various mangrove management strategies, an intercept survey was used. We conducted a paper questionnaire distributed on Moloka'i during June 2015 with the intent of sampling a minimum of 200 adult Moloka'i residents. Participants were required to be 18 or older and have lived on Moloka'i for two or more years. A quasi-chain sampling method was employed with some individuals providing additional participants or intercept venues. Surveys were distributed by researchers trained on distribution methods and survey content to residents at venues including the Moloka'i Ka Hula Piko (hula festival), a local grocery store, Saturday market, local churches, and the high school.

Measures

The questionnaire included 32 questions, comprised of Likert-scale response, multiple choice, and open-ended response items. Questions assessed respondents' attitudes towards Moloka'i's mangroves, threats to Moloka'i's coastal areas, and support for management of Moloka'i's mangroves using a 7-point Likert-scale that ranged from "Strongly Agree" (3) to "Strongly Disagree" (− 3), with a midpoint of "Neither Agree nor Disagree" (0). Awareness of benefits and costs of mangroves was measured on a 7-point Likert-type scale that ranged from "Very Well Informed" (3) to "Very Uninformed" (− 3). The frequency of interaction with mangroves was measured on a 5-point unipolar scale that ranged from "Never" to "Daily". Using a 7-point Likert scale, condition of Moloka'i's southern coast was measured on a range from "Very Healthy" (3) to "Very Unhealthy" (− 3), and the quality of management of Moloka'i's southern coast was measured using a range from "Very Well Managed" (3) to "Very Poorly Managed" (− 3). We did not indicate that mangroves were non-native on the questionnaire.

Data analysis

Summary statistics on attitudes towards mangroves were used to quantify residents' attitudes towards non-native mangroves (question 1). Responses to three attitude items (harmful, beneficial, and improve coastal quality) were averaged into a summary index due to high correlations and conceptual consistency. Cronbach's alpha was used to measure the attitude index's internal consistency (0.70–0.90 is considered adequate) (Cronbach 1951; Tavakol and Dennick 2011). This index was then used to determine what influences attitudes towards non-native mangroves (question 2), and finally used as a predictor when assessing support for management strategies (question 3).

The attitude index ranged from − 3 to 3 with negative numbers indicating a negative attitude, 0 indicating a neutral attitude, and positive numbers indicating a positive attitude. The attitude index was transformed into a binary variable based on the valence of the attitude index: negative (1), positive/neutral (0). Logistic regression was used to predict the negative attitude towards non-native mangroves. Some predictor variables were indexed due to theoretical considerations confirmed by high correlations, and Cronbach's alpha was used to measure internal consistency. As mangrove management planning is ongoing, logistic regression provides important information about influences on the odds of holding negative attitudes that may provide important information when deciding on management actions. A full logistic regression model was built using all variables from Tables 1 and 2 except management actions. The full model was then reduced by removing variables that increased the Akaike Information Criterion (AIC) using a hybrid (stepwise and criterion based) approach. We used Variance Inflation Factor (VIF) to assess the model for multicollinearity issues, with a VIF greater than or equal to 4 indicating possible collinearity. VIF was less than 2 for all variables in the full and reduced models. We assessed how well the model fit the data by using a Chi^2 test of the deviance of the residuals, where a p value greater than 0.05 indicates the model fits the data well. The McFadden and Nagelkerke R^2 values were calculated to further evaluate model fit compared to a null model. A likelihood ratio test was used to compare the full logistic model to the reduced logistic model to ensure the model was not overly reduced. Variables were standardized to make coefficients comparable.

The final research question was assessed using ordinary least squares (OLS) regression to predict what attitudes and perceptions influence support of specific management approaches. Several aspects of management were modeled, including the perceived quality of coastal management and support for active management, leaving mangroves alone, and eradicating mangroves from Moloka'i's coast altogether. A full model was built for each management activity, then reduced by removing variables that increased Akaike Information Criterion (AIC) from that of the null model's using a hybrid (stepwise and criterion based) approach. The Variance Inflation Factor (VIF) was again used to assess all models for potential multicollinearity. VIF was less than 2 for all variables in the full and reduced models. A likelihood ratio test was used to compare the full and reduced models. Variables were standardized to make coefficients comparable. All statistical analyses were performed using "R" version 3.2.2.

Results

Descriptive results

A total of 204 survey responses were collected (Table 1). Relative to Moloka'i's general population (US Census 2014), respondents were more female (65% survey; 51% census) and older (median age range of respondents was 46–50 years; median age per US Census of Moloka'i residents was 38 years). Respondents also had a higher level of education (41% of the survey respondents had a bachelor's degree or higher, compared to 21% on the census of Moloka'i residents; US Census 2014). The median household income reported by the US Census for Moloka'i was $42,415 and 54.7% of survey respondents reported an income less than $50,000. Respondents were asked two separate questions; how long they have lived on Moloka'i and how long they have lived in the Hawaiian Islands. Residence times ranged from two to over 81 years, with averages of 31 years on Moloka'i and 40 years in the Hawaiian Islands.

Responses to three 7-point Likert-style questions were assessed to examine general attitudes towards mangroves (Table 2). When asked if mangroves on

Table 1 Summary of demographic and place connection variables

Variables	Mean (SD)	%	N
Total responses			204
Demographics			
Gender			195
Female (1)		65.1	
Male (0)		34.9	
Household income			181
Less than $25,000 (1)		25.4	
25,000–$49,999 (2)		29.3	
50,000–$74,999 (3)		23.8	
75,000–$99,999 (4)		11.6	
Greater than $100,000 (5)		9.9	
Place connection			
Lived on Moloka'i (years)	30.7 (17.5)		194
Lived in Hawai'i (years)	39.0 (18.1)		194
Hawaiian or Pacific Island ethnicity			203
Yes (1)		61.8	
No (0)		38.2	

Moloka'i are beneficial, the plurality of respondents (43%) agreed, while 33% disagreed (the remainder were neutral). In comparison, when asked if mangroves on Moloka'i are harmful, nearly half (49%) agreed, while only 21% disagreed. When asked whether mangroves improve the coast, about a quarter (24%) agreed, while the plurality (45%) disagreed. Correlations among these three items averaged 0.66 indicating consistency among the attitude measures towards Moloka'i's mangroves. The three attitude items were averaged to create a mangrove attitude index (mean = − 0.33, median = 0, standard deviation = 1.44; ranging from − 3 to 3) with a Cronbach's alpha of 0.87. Overall, 48% of respondents had a negative attitude, 21% neutral, and 31% positive toward mangroves. There were no major perception differences based on the demographics of gender and Native Hawaiian/Pacific Island ancestry versus others.

Respondents reported feeling informed (48%) when considering benefits and costs of Moloka'i's mangroves (Table 2). While 85% of survey respondents reported visiting the mangroves in person, over 50% interacted with them at least annually and 46% rely on mangroves for some benefit. Over 20% of respondents reported using mangroves for two or more benefits, with crabbing and fishing being the highest reported benefits. Nearly half (14) of the 32 written responses also reported using mangroves for building material. Although only 42% of respondents described Moloka'i's southern coast as unhealthy, 78% identified sedimentation, runoff, and invasive species as concerns.

With respect to management, respondents tended to indicate that the quality of coastal management on Moloka'i's southern coast was poor with 50% of respondents indicating that the quality of management was somewhat, poorly, or very poorly managed, whereas only 19% indicated that management quality was somewhat, well, or very well managed. On average, respondent attitudes toward public involvement in mangrove management tended to be neutral, with slightly more respondents agreeing (36%) than disagreeing (26%) that mangrove management decisions consider public input and all interests and values. Support for complete mangrove removal (41%) was slightly favored relative to those opposing complete removal (36%), but neither group were in a majority. Nonetheless, respondents were overwhelmingly opposed to leaving them alone (76%; versus 9% who supported leaving them alone) and were overwhelmingly in support of active management of mangroves (88%; versus < 4% opposed to active management). Among the 88% in favor of active management, 24% of written in responses expressed a need for maintaining the benefits of mangroves and 67% described reducing the negative impacts, while 4%

Table 2 Summary of variables related to mangroves and coast conditions

Variables	Mean (SD)	N	% +	% -	α
Attitudes					
Attitude towards Moloka'i's mangroves index	− 0.3 (1.4)	197	31.2	48.0	0.87
Beneficial[a]	− 0.1 (1.7)	200	42.5	33.0	
Harmful[a,†]	0.5 (1.6)	197	49.3	21.3	
Improve the coast[a]	− 0.5 (1.6)	197	24.7	45.2	
Values and experience and awareness					
Familiarity with costs/benefits of mangroves[b]	0.3 (1.5)	197	47.7	24.9	
Have visited mangroves (0/1)	0.9 (0.5)	199	85.4	14.6	
Mangrove interactions[c]	1.7 (1.6)	203	–	–	
Frequency of interaction (days per year)	30.5 (1.3)	199	–	–	
Rely on mangroves for benefit (0/1)	0.5 (1.0)	201	46.2	53.8	
Coast concerns					
Condition of Moloka'i's southern coast[d]	− 0.3 (1.3)	200	29.5	42.0	
Coastal threat index	1.8 (1.0)	201	91.0	3.0	0.73
Sedimentation is a concern for Moloka'i's coast[a]	1.7 (1.2)	197	80.2	3.1	
Chemical runoff is a concern for Moloka'i's coast[a]	2.3 (1.4)	197	78.7	6.6	
Invasive species are a concern for Moloka'i's coast[a]	2.0 (1.1)	201	86.6	1.5	
Mangroves hurt cultural sites[a]	0.8 (1.5)	193	52.9	12.4	
Mangroves hurt industry[a]	0.0 (1.4)	193	22.3	23.8	
Management					
Quality of management on Moloka'i's southern coast[e]	− 0.6 (1.3)	199	18.6	50.3	
Public involvement in management index	0.2 (1.4)	195	36.4	25.6	0.91
Decisions about mangroves made with consideration of public input[a]	0.2 (1.5)	193	35.2	23.3	
Decisions about mangroves made with consideration of all interests and values[a]	0.2 (1.5)	191	36.1	24.6	
Mangroves should be entirely removed[a]	0.2 (1.9)	198	40.9	36.4	
Mangroves should be left alone[a]	− 1.5 (1.5)	199	9.1	76.4	
Mangroves should be actively managed[a]	2.0 (1.2)	199	88.4	3.5	

Items in italics are indices comprised of the items indented below; Cronbach's alpha (α) is reported as a measure of internal validity of indexed items

[a]Variable ranged from strongly disagree (− 3) to strongly agree (3) with neither agree nor disagree (0) as a midpoint

[b]Variable ranged from very uninformed (− 3) to very well informed (3) with unsure (0) as a midpoint

[c]Mangrove interactions were measured as the number of interaction types respondents had with mangroves (e.g., fishing, managing mangroves in fishponds, etc.) and ranges from 1 to 5

[d]Variable ranged from very unhealthy (− 3) to very healthy (3) with unsure (0) as a midpoint

[e]Variable ranged from very poorly managed (− 3) to very-well managed (3) with unsure (0) as a midpoint

[†]For index creation, this item was reverse coded for logical consistency

acknowledged both the benefit and harm the species has on the environment.

Mangrove attitude regression

A logistic regression model was constructed to predict negative attitudes towards non-native mangroves, which roughly half of respondents held (Table 3). The model was a significant improvement over a null model and the likelihood ratio test revealed no significant difference between the full and reduced models (χ^2 $p = 0.64$, Nagelkerke $R^2 = 0.51$, McFadden $R^2 = 0.35$). Predictors of a negative attitude included the belief that mangroves harm cultural sites,

Table 3 Logistic regression predicting differences between positive/neutral (0) and negative (1) attitudes towards non-native mangroves (coefficients are standardized)

	Standardized coefficients	SE	Odds	95% confidence interval
Intercept	0.08	0.22	1.08	(0.70–1.68)
Income	0.62**	0.24	1.86	(1.18–3.02)
Rely on mangroves for benefit	− 0.79**	0.24	0.45	(0.28–0.72)
Mangrove cost/benefit familiarity	0.53*	0.24	1.69	(1.07–2.73)
Positive condition of South coast	− 0.44†	0.23	0.65	(0.40–1.01)
Coastal threat index	0.94**	0.29	2.55	(1.50–4.62)
Mangroves hurt cultural sites	0.72**	0.24	2.05	(1.31–3.34)

N = 146 (74 negative, 72 positive/neutral). McFadden $R^2 = 0.35$, Nagelkerke $R^2 = 0.51$. χ^2 $p = 0.64$

P Value significance levels: $^{\dagger} < 0.10$; * < 0.05; ** < 0.01; *** < 0.001

the belief that sediment runoff and invasive species threaten the coast, increased familiarity with the costs and benefits of non-native mangroves, as well as higher income levels and a lack of reliance on mangroves. Beliefs that mangroves harm cultural sites may be related to experience with damage to traditional Hawaiian fishponds from mangrove encroachment. Finally, although the belief that the coast was "generally healthy" failed to meet our $\alpha = 0.05$ test for a significant association with a negative attitude towards mangroves, the negative sign of the coefficient suggests that residents with a positive view of the health of Moloka'i's coast may be more likely to hold positive or neutral attitudes towards Moloka'i's non-native mangroves.

Support for mangrove management strategies

An ordinary least squares (OLS) regression was used to predict support of various non-native mangrove management characteristics (Table 4), including the quality of coastal management on Moloka'i's southern coast, and support for not managing, eradicating, and active management of Moloka'i's mangroves. Reduced models were developed to be parsimonious and for all models, the likelihood ratio test revealed no significant difference in model fit between full and reduced models. The first model predicted respondent perceptions on the quality of Moloka'i's southern coastal management. Only about 19% of respondents perceived Moloka'i's southern coast to be well-managed, and the capacity of the regression model to predict management quality beliefs was relatively strong (adjusted $R^2 = 0.54$). Belief about management quality was significantly influenced by respondents concerns for the coast and their experience and awareness of mangroves. Agreement that coastal management was beneficial was greatest from respondents who perceived the condition of Moloka'i's southern coast as healthy, had low concern for coastal threats, found mangroves less influential on cultural sites, had less frequent interaction with mangroves, and lower perceived familiarity with costs and benefits of mangroves.

Support for leaving mangroves alone was also generally low (9%), although the capacity of the regression model to predict agreement or disagreement for leaving mangroves alone was moderately strong (adjusted $R^2 = 0.34$). Respondents who believed in leaving Moloka'i's mangroves alone tended to hold positive attitudes toward mangroves and had resided less time in Hawai'i. Having fewer or no interactions with mangrove habitat was suggestive of support for not managing Moloka'i's mangroves. Support for complete removal of mangroves was much higher (41%) than support for leaving them alone, and was more strongly predicted (adjusted $R^2 = 0.54$) by negative attitudes towards mangroves, having lived on Moloka'i longer, having a lower household income, having greater perceived familiarity with the costs and benefits of mangroves. Not reporting use-related benefits from mangroves was also suggestive of support for eradicating Moloka'i's mangroves. Finally, support for active management to achieve a mix of societal goals was the most commonly supported strategy (88%), but support for active

Table 4 Ordinary least squares regression results predicting extent of support for mangrove management

	Overall quality of coastal management	Mangroves should be left alone	Mangroves should be entirely removed	Mangroves should be actively managed
Intercept	0.06	0.05	− 0.15	0.66***
Income			− 0.19*	
Years in Hawai'i		− 0.01*		
Years on Moloka'i			0.02**	
Attitude towards mangroves		0.45***	− 0.94***	
Rely on mangroves for benefit			− 0.44†	
Log (frequency of interaction)	− 0.17	− 0.34*		
Have visited mangroves		− 0.54†		0.41†
Mangrove cost/benefit familiarity	− 0.11*		0.16*	
Positive condition of South coast	0.543***			0.11†
Coastal threat index	− 0.177*	− 0.15		0.33***
Mangroves hurt cultural sites	− 0.133*			0.22***
Mangroves hurt industry				
Model fit				
Adjusted R^2	0.54	0.34	0.54	0.26
N	150	152	152	151

Standardized coefficients are presented. A likelihood ratio test revealed no significant difference between the full and reduced models

P Value significance levels: † < 0.10; * < 0.05; ** < 0.01; *** < 0.001

management was relatively less predictive than the other models (adjusted $R^2 = 0.26$). Concerns about coastal threats and agreeing that mangroves are a threat to cultural sites were significant predictors of support for active management, while experience visiting the mangroves and perceiving a healthy southern coast both suggested support for active management.

Discussion

Overall, residents of Moloka'i who responded to our survey tended to view their southern coast as unhealthy and under threat. Attitudes towards non-native mangroves were divided with 48% of respondents holding negative attitudes and 31% holding positive attitudes. Numerous responses to open-ended questions revealed deeper insight to this division. While many who viewed mangroves in a negative light elaborated on their non-native nature, those who viewed them positively described improved ecosystem functions and human benefits from their use. Overwhelmingly, respondents agreed that mangroves should be actively managed, and the lower predictability of support for active management may be indicative of an opportunity for managers to build support from residents of Moloka'i with divergent attitudes about Moloka'i's mangroves if both the benefits and the consequences of this established non-native species are recognized and incorporated into future natural resource management practices.

Attitudes towards non-native mangroves

Individuals' attitudes are formed from experiences and interactions with their social and natural environment (Schwarz and Bohner 2001; Balram and Dragićević 2005). Survey respondents confirmed the tendency towards a negative attitude about non-native species (Slobodkin 2001; Gurevitch and Padilla 2004; Stromberg et al. 2009). Despite the negative attitude tendency, nearly a third of residents maintained a positive attitude towards Moloka'i's mangroves, and another fifth of respondents were neither positive nor negative, indicating that nearly half of respondents were either uninformed, have little basis for an attitude (perhaps resulting from a lack of contact with mangroves), or receive some benefit from Moloka'i's mangroves that result in a positive relationship. Twenty-one (11%) respondents expressed conflicted views and simultaneously identified both pros and cons of mangroves. Thirty-seven (19%) respondents answered "neither agree or disagree" to all questions associated with attitude toward mangroves. Since residents may feel less inclined to participate in local issues if they are uninformed, understanding mangrove attitude profiles may highlight an educational opportunity.

A considerable number of respondents (31%) had positive attitudes about mangroves, many of whom indicated through open-ended comments on the questionnaire a perception that mangroves provide important habitat and regulating ecosystem services by controlling sedimentation and reducing erosion runoff to the near-shore coral reefs. For example, one respondent exemplified these beliefs in a written comment on their completed questionnaire, "[mangroves provide] new habitat for coastal species [and] stop runoff from reaching [the] ocean and stops coastal erosion". These are important services that mangroves provide in their native habitat (Ewel et al. 1998; Mcleod et al. 2011) that have not been fully evaluated on Moloka'i nor in other locales with non-native mangroves. Though a small study on West Moloka'i showed water turbidity was lower on coral reefs adjacent to mangroves than on reefs with no adjacent mangroves (Bigelow et al. 1989) and another limited study (4 sites) showed non-native mangroves provide additional habitat but many of the species that reside within them are also non-native (Demopoulos and Smith 2010). Respondents that reported using mangroves for beneficial uses also tended to report positive attitudes, which may reflect normalization to the species' presence and recognition of its benefits and usefulness. Changes in normative values may also be evident through the formation of citizen groups mobilized to protect non-native species (Schlaepfer et al. 2011). Citizen organization around non-native species protections has been documented for dingo in Australia and for *Eucalyptus* trees and Red-masked Parakeets in California (Schlaepfer et al. 2011).

More respondents (48%) had a negative than positive attitude towards mangroves. Negative attitudes towards Moloka'i's non-native mangroves are congruent with and may be influenced by broader negative attitudes toward invading non-native, non-agricultural species (Schlaepfer et al. 2011). Although some respondents (13%) wrote in that mangroves were harmful solely because they were non-native or invasive, a larger portion of respondents wrote in that overgrowth was a concern (22%), expressing concerns about the effects of mangroves on local fishponds, ocean access, and views. The physical protection that fishponds create along with few competitors in the nearshore environment provides ideal conditions for mangroves to colonize (Chimner et al. 2006). Future studies may be able to gain further insight into whether the public views mangroves or other non-native species negatively solely because they are non-native or because of their invasive properties. Negative beliefs tend to be more influential and exercise a stronger influence on judgments and attitudes than positive beliefs (Fiske and Taylor 1991; Cacioppo et al. 1997), and ultimately can exert stronger effects on behavior (Eagly and Chaiken 1998). Individuals with negative attitudes may be more likely to express these feelings (vocally or with action), especially if management decisions are not in accordance with their attitudes and perceptions. In Hawai'i, mangrove management activities, including removal by chainsaw and chemical poisoning, reflect the negative beliefs many have about this non-native species (MacKenzie and Kryss 2013; Goecke and Carstenn 2017). In contrast, mobilization of effective advocacy coalitions (Sabatier 1988) by those with positive beliefs towards mangroves is not a phenomenon that we are aware of; however, citizen mobilization by those who hold positive attitudes towards mangroves is plausible as a response to continued mangrove removal efforts in Hawai'i, and managers should be aware of this potential.

Building blocks of attitudes towards non-native mangroves

Determining what variables influence attitudes is important as strong attitudes are known to be resistant to change, persist over time, lead to selective information processing, and be predictive of behavior (Eagly and Chaiken 1998). Respondents who considered themselves well informed on costs and benefits of Moloka'i's mangroves were more likely to have a negative attitude towards mangroves. Whether those with negative attitudes selectively seek negative information that makes them feel more informed or whether being well-informed leads to negative attitudes is unclear. Future research on attitudes of Hawaiians may clarify the public's actual level of knowledge and understanding, as well as their sources of information and the causal sequence between knowledge acquisition and negative attitudes towards non-native or invasive species. The distinction is important as stakeholders may oppose management decisions if those decisions are not in accordance with their attitudes and perceptions, and may offer opportunities for managers to educate the public about both the costs and potential benefit of non-native species.

Though previous studies have noted economic costs of aquatic invasive or non-native species (Lovell et al. 2006), relatively few have quantified economic benefits (Schlaepfer et al. 2011). Positive and neutral attitudes towards Moloka'i's mangroves were more common among respondents who use mangroves for their benefit. Value is a demonstrated component of general environmental attitudes and can manifest in management support or opposition (Balram and Dragićević 2005; Selge et al. 2011). With 46% of respondents relying on mangroves for some benefit, a large proportion of respondents have learned to utilize this non-native plant to their advantage. Nonetheless, utilizing mangroves for benefits must be balanced against negative effects of mangroves, such as affecting cultural sites through encroachment or damage to traditional fishponds, which may lead to a more negative view of mangroves. This dichotomy of perception that non-native species can be recognized as negative and positive by different parts of the population has been documented in Papua New Guinea where local people have been known to spread non-natives due to their potential use as a commodity (Dudgeon and Smith 2006).

Place connection is a fundamental reason why people partake in action to protect natural areas (Norton and Hannon 1997; Vaske and Kobrin 2001; Lokocz et al. 2011; Nielsen-Pincus et al. 2017) and may facilitate support for certain management actions. Since time in an area can lead to a stronger connection to place (Gieryn 2000; Lewicka 2005) and as the median length of residency for our respondents on Moloka'i was 31 years, it is likely that many have developed a strong sense of place. We also recognize that mangroves have been a part of Moloka'i's coastal ecosystem for the entire lifespan of every resident potentially making them a part of Moloka'i residents' sense of place, which may contribute to positive feelings towards Moloka'i's mangroves through nostalgia, regardless of potential negative impacts. Conversely, mangroves have expanded significantly since introduction and residents may notice changes occurring due to their presence. Further, expanding the spatial extent of this study to other regions with varying time since mangrove introduction would provide deeper insights into how perceptions change over time. When respondents perceived coastal threats such as sedimentation, invasive species, and chemical runoff, they were more likely to view mangroves negatively. While 91% of respondents perceived coastal threats, only 42% found the condition of Moloka'i's southern coast as unhealthy. This relationship may indicate that respondents held complex beliefs concerning mangroves and coastal health. Through open response questions, it was evident some respondents view mangroves as providing sediment retention and runoff filtration leading to a healthier coast, while other respondents who agreed that Moloka'i's coast was threatened had negative attitudes about mangroves suggesting that mangroves are part of the problems faced by the coastline. Local populations in India and Bangladesh have recognized native mangrove benefits including ecosystem functions such as protection from floods and storms and erosion prevention (Iftekhar and Takama 2008; Badola et al. 2012). Though some Indians had concerns of human wildlife-conflict with crocodiles, cooperation with conservation management of mangroves was likely due to local participation in conservation (Badola et al. 2012). Conflicting perceptions of whether mangroves are reducing coastal threats or contributing to them may provide an opportunity to improve knowledge gaps concerning

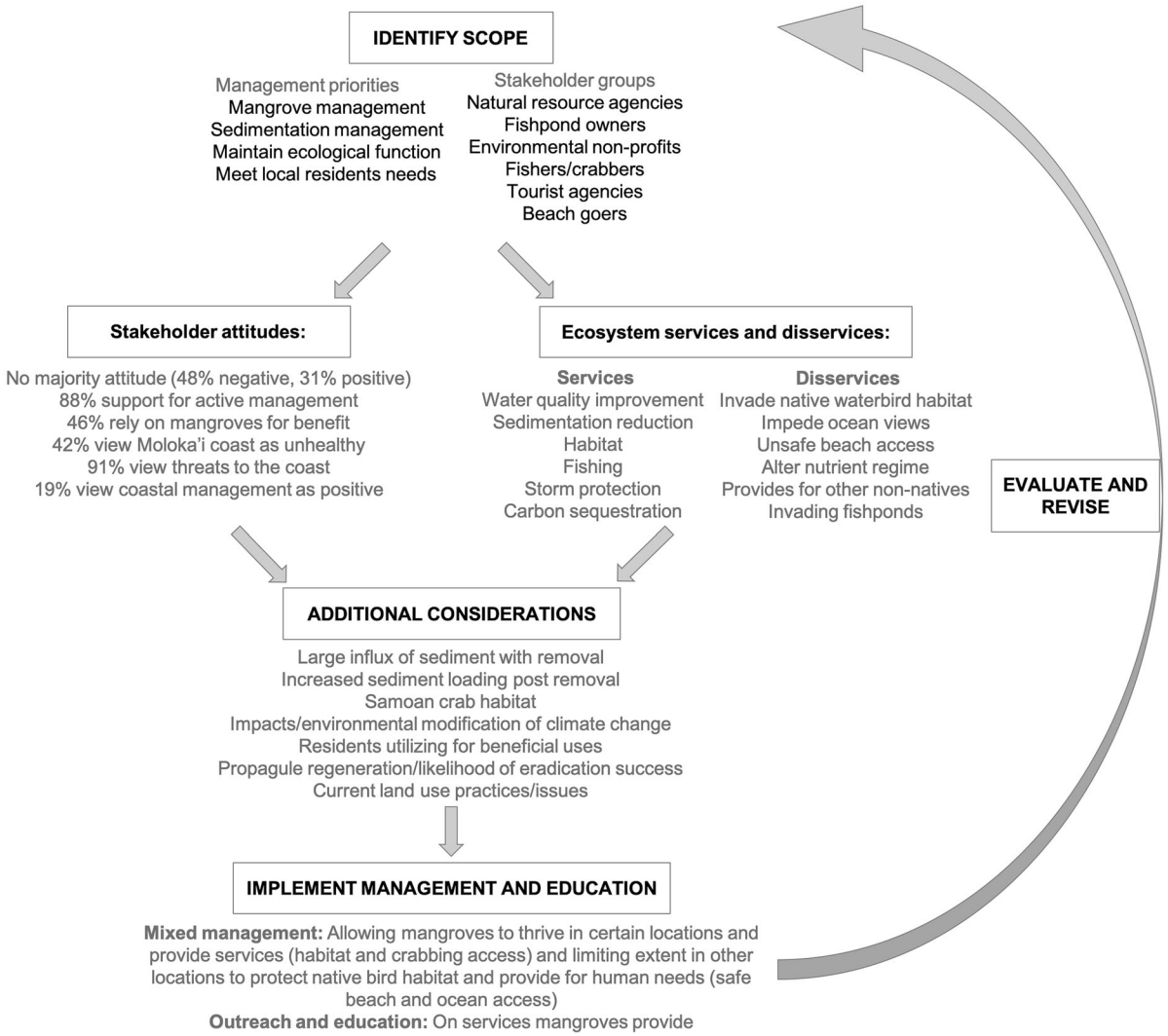

Fig. 2 Case study findings in the framework for optimizing novel ecosystem management through consideration of stakeholder socio-cultural attitudes and values

the ecosystem services provided by Moloka'i's mangroves and to conduct further research to understand the mental models individuals use to interpret the role mangroves play in the health of Moloka'i's coast.

Attitudes and management: assessing levels of management support

Understanding and incorporating public attitudes into biodiversity management decisions can lead to greater support for management and translate into increased project success (Fischer and Van Der Wal 2007). Support of various management actions was influenced by attitudes towards mangroves, concerns about Moloka'i's coast, and experience with Moloka'i's mangroves. Similar attributes have been found in other studies looking at public support for or opposition to non-native species management (Genovesi 2007; Selge et al. 2011). As attitudes are one predictor of behavior (Ajzen 1985) and negative attitudes are more likely to result in behavior than positive attitudes (Eagly and Chaiken 1998), management planning should investigate stakeholder attitudes to minimize conflict and better inform how management plans may be perceived and acted on by the public (Fig. 2).

More specifically, when considering respondents' perception of management quality along Moloka'i's southern coast, the healthier the respondents' perception of Moloka'i's southern coast, the better the quality of management they perceived. This association has been documented previously where simple perceptions of beauty can serve as a determinant of acceptable management, though this relationship becomes more complex when comparing between people with substantially different natural resource management attitudes (Ribe 2002). However, when these differences are accounted for, then beauty and ecosystem health can be a fair measurement of perceived acceptability of management (Ribe 2002). This relationship suggests that successful coastal management is perceived as a function of coastal health and provides a simple and straightforward evaluation of the coast and its management practices. Further questioning could investigate whether scenic beauty, fishery health, or other more detailed evaluations provide additional insight about how individuals evaluate the quality of management.

The concern of mangroves damaging cultural sites (e.g., traditional fishponds) and the perception of coastal threats (e.g., sedimentation, runoff, invasive species) were most predictive of support for active management of Moloka'i's mangroves. Support for active management is also evident where non-native species have established in other locations (Schlaepfer et al. 2011). Eighty-eight percent of respondents agreed that Moloka'i's mangroves should be actively managed. Non-native mangroves may provide beneficial ecosystem services such as reducing coastal storm damage while also creating disservices such as overgrowing fishponds and shorebird habitat. This dichotomy of socio-ecological costs and benefits can be difficult for managers to balance, but survey responses indicate that Moloka'i residents recognize an array of ecosystem effects generated by non-native mangroves. This dichotomy is evident in other areas of the world where restoration efforts for mangrove forests have been undertaken. For example, local residents in Bangladesh identified increased human-wildlife conflicts as habitat is restored, but many also depend on and can identify mangrove services (Iftekhar and Takama 2008). In Spain, García-Llorente et al. (2008) found that recognition of the economic and recreational benefits of non-native species lead to people being less willing to contribute to eradication efforts even though they also identified harmful ecosystem impacts from non-native species. Therefore, clear communication between managers and the public about the tradeoffs of different management strategies may be an important tactic for managers.

Conclusion

The experiences and interactions that residents of Moloka'i found valuable provide insight into what residents deem important and drive their positive and negative attitudes. The implications of these findings are relevant to environmental management actions more broadly and can increase the likelihood of public support in a variety of settings (Fischer and Van Der Wal 2007). On Moloka'i, there was near consensus among survey respondents (88%) that Moloka'i's non-native mangroves should be actively managed. An active management approach allowing mangroves to thrive and provide services such as habitat and crabbing access in certain locations, while in other locations limiting their extent to protect native bird habitat and provide for human needs, including safe beach and ocean access, may ultimately provide the greatest benefits to both the ecosystem and society. However, managers may need to clearly communicate the tradeoffs of different management strategies as a tactic to demonstrate their understanding of the different attitude profiles common among stakeholders. Although we did not perform an in-depth economic analysis of different management options, any management actions would likely be costly. Mangrove removal is expensive, regardless of whether it is to manage their extent or an attempt to eradicate them. Due to the length and extent of mangrove establishment in Hawai'i, eradication may not be possible (Allen 1998; Chimner et al. 2006) and any attempt may produce continual expenses similar to those of managing their extent in certain areas. Nevertheless, cost of management plays a large role in success and feasibility and will need to be considered. In addition, the full impacts of mangrove removal should be evaluated before implementation (Chimner et al. 2006) because studies have shown ecosystem effects can be persistent even after mangrove removal (Sweetman et al. 2010). Finally, we did not compare resource use in areas with and without

mangroves; doing so may help improve our understanding of the impacts of maintaining or removing mangroves in different areas.

The findings from this and other studies offer a framework for assessing knowledge, attitudes, and perceptions about socio-ecological costs and benefits of non-native species in this and other locales. The framework also offers targets for educational efforts that may increase awareness about non-native species and allow for broader and more effective stakeholder engagement in management planning (Fig. 1). The combination of social and ecological research allows managers to objectively develop management options and educational targets that will provide more valuable and cooperative stakeholder engagement. The integrated approach, which requires recognition of ecosystem services and human valuations contrary to the prevailing negative attitude against non-native species, may lead to more pragmatic and objective decisions (Walther et al. 2009; Schlaepfer et al. 2011). In doing so, our framework provides a basis for evaluating other non-native species to better understanding the net impacts of introductions.

In our globalized world, non-native introductions to coastal ecosystems will continue to have both positive and negative effects that vary over time. Mangroves will continue to expand their range as the climate warms (Demopoulos et al. 2007; Demopoulos and Smith 2010) creating additional areas facing natural resource dilemmas. Range alterations are not limited to mangroves and can generate difficult questions in terms of management. In areas where established non-natives are utilized for beneficial uses, management strategies may garner stronger support if they allow for the future use of the species. For newly, unintentionally introduced species, local use and benefits are less likely to manifest instantly and eradication may be appropriate. Length of establishment, implications of invasions, and how locals interact with the non-native species are critical to determining appropriate management actions that can garner local support. Human perceptions towards novel ecosystems created by non-native introductions, especially foundation species, are likely to change over time and require an array of management approaches (Maris and Béchet 2010). There may be locations where non-native species fulfill ecosystem functions no longer provided by extirpated native species or where new functions are needed due to changing land cover or global environmental conditions (Truitt et al. 2015). Predicting the socio-cultural and ecological effects of these non-native species is increasingly difficult under changing environmental conditions (Walther et al. 2009). Yet considering diverse perspectives through an understanding of local attitudes and factors influencing those attitudes allows for a more comprehensive evaluation of the positive and negative effects of non-native species to facilitate more effective management with greater public support (Balram and Dragićević 2005; Bremner and Park 2007; Fischer and Van Der Wal 2007).

Acknowledgements Thanks to Joey Peters, Raymond Leimana Naki, Ka Honua Momona, fishpond owners, and Colette Machado for assistance with survey distribution; Shelby Oliver for data entry; and 204 Moloka'i residents for their contribution to this project.

Financial support This work was supported by a Portland State University Faculty Enhancement Grant (to EFG).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standards Portland State University Institutional Review Board reviewed and approved survey materials and methods (#153446).

Appendix: Survey instrument

Consent

We are looking for adult residents of Molokai who have lived here a year or more who would be willing to answer a survey on the mangroves of Molokai. Your participation in this study is voluntary.

The survey is part of a Faculty Enhancement Grant funded project and will be a component of a masters thesis project on the ecosystem services of non-native mangroves in Hawaii. The survey asks questions to assess public perceptions and attitudes about and understanding of mangroves and their management.

We do not anticipate any risks with participating in this survey. No personal information will be stored with your responses. Your participation in the survey is voluntary. We are not offering any compensation for participation. It is completely up to you if you want to participate, and you can skip questions.

The survey will take about 5-10 minutes. No personal information will be collected, and your responses will be kept strictly confidential and individual responses will not be shared with any person or group not directly involved in the survey.

A. Demographics

A1. What is your gender?

___Male	___Female

A2. Please select your age range?
___ 18-21
___ 21-25
___ 26-30
___ 31-35
___ 36-40
___ 41-45
___ 46-50
___ 51-55
___ 56-60
___ 61-65
___ 66-70
___ 71-75
___ 76-80
___ over 80 yrs.

A3. What is your ethnicity?
___ American Indian or Alaska Native
___ Asian
___ Black or African American
___ Hispanic or Latino
___ Native Hawaiian or Other Pacific Islander
___ White
___ Other

A4. What is the highest degree or level of school you have completed?
___ Less than high school
___ High school
___ Some college
___ Associated or Vocational degree
___ Bachelor's degree
___ Some graduate school
___ Graduate or professional degree

A5. What is your current employment status?
___ Employed full time
___ Employed part time
___ Unemployed
___ A homemaker
___ Student
___ Retired

A6. What category best describes your household income (before taxes) in 2014?
___ Less than $25,000
___ $25,000 - $49,999
___ $50,000 -$74,999
___ $75,000 - $99,999
___ $100,000 and higher

A7. What is your main source(s) of income?

_____

A7. How long have you lived on Molokai?

_____

A8. How long have you lived in the Hawaiian Islands (in years)?

_____

B. Molokai Mangroves

Below are 22 statements about the Molokai mangroves. For each statement, please select the option that matches your assessment. If you Strongly Agree, Agree, or Somewhat Agree with a statement, we invite you to provide additional information below that statement.

B1. Do you rely on mangroves for any benefit? Please mark all that apply.
___ Fishing
___ Crabbing
___ Spiritual/cultural benefits
___ Tourism
___ Recreation
___ Other _____
___ None

B2. In what way to you interact with the mangroves (for each of the below, circle a response):

a. Visitation

Never	Yearly	Monthly	Weekly	Daily

b. Fishing in the mangroves

Never	Yearly	Monthly	Weekly	Daily

c. Managing mangroves in fishpond(s)

Never	Yearly	Monthly	Weekly	Daily

d. Managing shoreline mangroves

Never	Yearly	Monthly	Weekly	Daily

e. Other _____

Never	Yearly	Monthly	Weekly	Daily

B3. How often do you interact with the mangroves?

Never	Yearly	Monthly	Weekly	Daily

B4. What is the condition of Molokai's southern coast?

Very Healthy	Healthy	Somewhat Healthy	Unsure	Somewhat Unhealthy	Unhealthy	Very Unhealthy

B5. How would you assess the quality of management of Molokai's southern coast?

Very Well Managed	Well Managed	Somewhat Well Managed	Unsure	Somewhat Poorly Managed	Poorly Managed	Very Poorly Managed

B6. The mangroves on Molokai should be actively managed.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

If you answered Strongly agree, Agree, or Somewhat agree, please state **WHY**.

_____

B7. The mangroves on Molokai should be left alone.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

If you answered Strongly agree, Agree, or Somewhat agree, please state **WHY**.

_____

B8. The mangroves on Molokai should be entirely removed.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

If you answered Strongly agree, Agree, or Somewhat agree, please state **WHY**.

_____

B9. Do you consider sedimentation a concern for the coast of Molokai?

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

B10. Do you consider chemical runoff a concern for the coast of Molokai?

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

B11. Do you consider invasive species a concern for the coast of Molokai?

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

B12. The mangroves on Molokai are beneficial.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

If Strongly Agree, Agree, Somewhat Agree, please state **in what way(s) they are beneficial:**

_____

B13. The mangroves on Molokai are harmful.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

If Strongly Agree, Agree, Somewhat Agree, please state **in what way(s) they are harmful**:

_____

B14. The mangroves improve the coast on Molokai.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

If you answered Strongly agree, Agree, or Somewhat agree, please state **How**.

_____

B15. The mangroves hurt industry on Molokai.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

If you answered Strongly agree, Agree, or Somewhat agree, please state **How**.

_____

B16. The mangroves hurt cultural sites on Molokai.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

If you answered Strongly agree, Agree, or Somewhat agree, please state **How**.

_____

B17. I feel like management decisions about the mangroves are made with consideration of public input.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

B18. I feel like management decisions about the mangroves are made with consideration of all interest and values.

Strongly Agree	Agree	Somewhat Agree	Neither Agree or Disagree	Somewhat Disagree	Disagree	Strongly Disagree

B19. How well informed would you consider yourself to be concerning the pros and cons of the mangroves?

Very Well Informed	Well Informed	Somewhat Well Informed	Unsure	Somewhat Uninformed	Uniformed	Very Uninformed

B20. Have you visited the mangroves in person?

Yes	No

B21. When did you first become aware of the mangrove issue?

_____

B22. Are you aware of issues that we have not asked about? If yes, please list:

_____

B23. Whose responsibility should it be to manage the mangroves?
List all that apply:

_____

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